Interventions to improve healthcare workers' hand hygiene compliance: a systematic review of systematic reviews

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Results based on a search of the literature up to June 2016 were presented previously on 19th September 2017 at the Annual Conference of the Infection Prevention Society, held in the

Manchester Central Convention Complex, England, United Kingdom. This presentation resulted in the following abstract:

Price, L., MacDonald, J., Gozdzielewska, L., et al. An overview of systematic reviews of interventions designed to improve healthcare workers' hand hygiene compliance. *J Infect Prev* 2017;18:S56-S57.

Abstract

Aim: To synthesise the existing evidence base of systematic reviews of interventions to improve healthcare workers' hand hygiene compliance. Methods: PRISMA guidelines were followed. Ten information sources were searched in September 2017, with no limits to language or date of publication, and papers screened against inclusion criteria for relevance. Data were extracted and risk of bias assessed. Results: Nineteen systematic reviews (n=20 articles) were included. Only one had a low risk of bias. Fifteen systematic reviews showed positive effects of interventions on healthcare workers' hand hygiene compliance (n=15), whereas three evaluating monitoring technology did not. Findings regarding whether multimodal than single interventions are preferable were inconclusive. Targeting social influence, attitude, self-efficacy, and intention was associated with greater effectiveness. No clear link emerged between how educational interventions were delivered and effectiveness. Conclusions: This is the first systematic review of systematic reviews of interventions to improve healthcare workers' hand hygiene compliance. There is sufficient evidence to recommend implementation of interventions to improve healthcare workers' hand hygiene compliance except for monitoring technology but insufficient evidence to make specific recommendations about the content and how the content should be delivered. Future research should rigorously apply behaviour change theory; be clearly described with respect to intervention content and how it is delivered ; and be tested longer-term using stronger study designs with clearly defined outcomes.

Introduction

Healthcare associated infection (HAI) have serious consequences for patients and healthcare systems, leading to longer hospital stay, increased mortality and morbidity, and financial burden[1,2] In Europe, approximately 80,000 hospital patients suffer at least one HAI on any given day, yielding an overall prevalence of 5.7%.[3] HAI also affect millions of patients worldwide annually.[3–7]

HAI causative organisms can be transmitted to patients through healthcare workers' (HCW) hands contaminated by patient contact or touching the patient environment[2] Effective hand hygiene (HH) is thus critical to prevent HAI,[8] emphasising the importance of HCW compliance with HH guidelines. HH guidance relates to both opportunity and technique. Opportunity concerns *when* to do HH; the World Health Organization (WHO) specify five moments.[2] Technique relates to *how* to enact HH, with two main procedures internationally: the six-step[2] and three-step[9] technique. However, HCW compliance with this guidance is suboptimal.[2,10–17]

A major challenge within healthcare systems, then, is how to improve hand hygiene compliance (HHC) among HCW. An early systematic review identified 21 primary studies evaluating HH interventions for HCW.[18] A plethora of primary studies and a growing number of systematic reviews have since assessed the effectiveness of interventions to improve HCW HHC. To assist practitioners, optimise HHC among HCW, this review aims to synthesise the evidence base of systematic reviews of interventions to improve HCW HHC.

Methods

Protocol and registration

This systematic review followed a published protocol[19] and is reported according to the PRISMA guidelines.[20]

Inclusion criteria

Systematic reviews were included if they evaluated any intervention to improve HHC among HCW. Interventions could have no comparator or be compared to usual care, another intervention, or historical control. Systematic reviews were required to report HHC as the primary outcome. Other outcomes of interest included bacterial load on HCW hands, HAI rates, organisational culture, and psychological variables. No restrictions were placed on the design of primary studies within systematic reviews.

Information sources and search

Four databases (CINAHL, EMBASE, MEDLINE, and PsycINFO) and six specialist registers (Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effectiveness, Epistemonikos, Joanna Briggs Institute Database of Systematic Reviews and Implementation Reports, Health Technology Assessment Database, and PROSPERO) were searched in September 2017. No language or date of publication restrictions were applied. The search included index terms and text words relating to HH[21] and systematic review methods.[22] Database searches were broadly similar; modifications were made to account for minor differences in functionality (see Table S1 for MEDLINE search). Due to limited functionality of specialist registers (except the Cochrane Database of Systematic Reviews); these searches were restricted to HH text words. Manual searching of reference lists of included systematic reviews was conducted.

Systematic review selection

Systematic review selection was done in two stages, with all papers assessed by two independent reviewers. First, titles and abstracts of included papers were screened against the inclusion criteria (LP, JM, LS, YW). Second, papers that appeared to meet the inclusion criteria or lacked sufficient information to allow an informed judgement on relevance underwent full-text review (LP, JM, LG, LS). Disagreements were resolved via discussion or referral to a third reviewer (LP, JM).

Data collection and risk of bias within systematic reviews

A standardised tool was devised for data extraction (Table S2). Risk of bias within systematic reviews was assessed using the ROBIS tool (Table S3).[23] Data were extracted and risk of bias assessed by two independent reviewers (LP, JM, LG) for 25% (n=5) of systematic reviews. The remaining systematic reviews were data extracted and assessed for risk of bias by one reviewer (LP, JM, LG) and checked by another (LP, JM, or LG). Disagreements were resolved through discussion or referral to a third reviewer (LP, JM, or LG).

Synthesis

Findings were synthesised following the Economic and Social Research Council's guidance for narrative synthesis.[24]

Results

Systematic review selection

The search yielded 993 papers (Figure 1). Following de-duplication, 566 unique papers remained; all were screened against the inclusion criteria. Most papers (n=481) were

discarded at the title/abstract stage, with 65 excluded at full-text review (reasons for full-text exclusions stated in Figure 1). Nineteen systematic reviews (n=20 articles) were included.[18,25–43] Reference list checks did not identify any further papers.

Systematic review characteristics

Characteristics of the 19 systematic reviews are summarised in Table S4. There were 15 narrative syntheses,[18,25–29,31,32,35,36/37,39–43] three meta-analyses,[33,34,38] and one network meta-analysis[30] published between 2001 and 2017, with 15 published after 2010.[25–33,38–43] Primary studies in included systematic reviews were published from 1986 to 2016 and ranged in number from three[41] to 73.[32] Collectively,[1] 236 unique primary studies were cited. However, some primary studies were included in more than one systematic review. The degree of overlap has been quantified and presented in a transparent manner:[44,45] 139 (58.9%) primary studies were cited once; 46 (19.5%) twice; 25 (10.6%) three times; 17 (7.2%) four times; seven (3.0%) five times; and two (<1%) six times.

Countries and healthcare settings

In all but two systematic reviews where inclusion was limited to primary studies conducted in developed[32] or low-/middle-income countries,[42] systematic reviews were open to primary studies from all countries. Regarding healthcare settings, 13 systematic reviews included primary studies conducted in hospitals.[25,26,28,30,31,33–35,39–43] Six systematic reviews included primary studies conducted in hospitals in addition to: care of the elderly homes;[29] nursing homes;[32] long-term care facilities; [27,32,36/37,38] care homes for people with disabilities;[18] and/or primary care.[27,29]

[1] Excluding primary studies in Ward et al.[43] because it is unclear exactly how many reported HHC and/or HAI outcomes and only including eight primary studies in Kingston et al.[29] with baseline and post-intervention HHC data, upon which conclusions about effectiveness were based.

Population

All systematic reviews were open to primary studies of any type of HCW, with Doronina et al.[26] the exception, specifying a particular professional group (nurses). Most systematic reviews included data from a range of HCW, such as, nurses, doctors, healthcare assistants, and students. Six systematic reviews had at least one primary study (n=1, [28,30,33,43] n=3;[40] n=6[32]) with data from patients or visitors/relatives; but, proportions of the overall samples that were not HCW are unknown.

Interventions

With regard to types of interventions, 11 systematic reviews took an inclusive approach. Others focused on the introduction of alcohol-based handrub (ABHR),[34] ABHR accessibility,[41] educational interventions,[25] interventions using psychological theory,[39] monitoring technology,[31,40,43] or quality improvement strategies.[35] Table S5 illustrates how the content of interventions evaluated in primary studies of each systematic review mapped onto the WHO multimodal strategy for HH.[2] The most frequent component was 'observation and feedback', mapped in all but one systematic review,[41] followed by 'training and education' (n=16)[18,25–39,42] and 'reminders' (n=15).[18,25–33,35,38,40,43] The least common component was 'safety climate', mapped in 10 systematic reviews.[25–30,32,35,38,43]

Outcomes

HHC was measured by direct (n=13)[18,26–30,32,33,36/37,38,39,41,42] or unobtrusive (n=2)[26,28] observation, video camera (n=4),[27,38,30,43] mobile handheld devices (n=1),[43] electronic monitoring (n=9),[27–29,31–33,38,40,43] or self-report (n=3).[32,36/37,42] Proxy measures, such as, rate or number of HH events (n=4),[27,28,30,40] ABHR consumption or soap use (n=11),[18,26–

[31,36/37,38,40,41] and procurement of ABHR or soap (n=2) [27,39] were also employed. A lack of longer-term evaluation of HHC was observed in 11 systematic reviews.[18,25–30,32,33,36/37,42] HAI rates were reported in 11 systematic reviews. [25,27,30,31,33,35,36/37,39,40,42,43] Bacterial load on HCW hands, organisational culture, and psychological variables were not reported in any systematic reviews.

Study designs

In three systematic reviews,[26,27,30] primary studies needed to meet Cochrane Effective Practice and Organisation of Care methodological criteria for randomised controlled trials (RCT), non-randomised trials, controlled before-after studies, or interrupted time series (ITS).[46] Across the other systematic reviews, before-after studies were common,[18,28,31–33,35,36/37,38–40] although five reviewers did not specify the design of included primary studies.[25,34,41–43] While Kingston et al.[29] described all primary studies as 'clinical trials', this term was not defined and ITS and before-after studies were included.[47]

Risk of bias within systematic reviews

Thirteen systematic reviews had a high risk of bias,[18,25,26,29,31–34,36/37,38,41-43] five systematic reviews had an unclear risk of bias, [28,30,35,39,40] and one systematic review had a low risk of bias (Table 1).[27] The most common methodological weaknesses within systematic reviews related to synthesis and findings, for example, not reporting individual study results, not including all primary studies in the synthesis, or not addressing biases in the synthesis. Other common methodological weaknesses within systematic reviews were not reporting a risk of bias assessment or the process for data extraction and risk of bias assessment.

Effectiveness of HH interventions

Hand hygiene compliance

Eighteen systematic reviews reported the overall effectiveness of interventions in improving HCW HHC (Table S6). Two meta-analysis showed similar increases (odds ratio (OR) 2.04, 95% confidence interval (CI) 1.40-2.97[33] and Peto OR = 1.96, CI = 1.56-2.46[34]). Luangasanatip et al.[30] found that 18 of 22 (82%) pairwise comparisons showed both stepwise increases in HHC during intervention implementation and a trend for increasing HHC post-intervention. In eight narrative syntheses, the majority of or all primary studies reported significant improvements in HHC. [25,26,32,35,36/37,38,39,41] Overall effectiveness is further supported by four narrative syntheses, which described positive findings, largely without reference to statistical significance.[27–29,42] Three narrative syntheses on monitoring technology found scarce evidence for effectiveness in improving HHC in general.[31,40,43]

Health-care association infection rates

In four systematic reviews, most of or all primary studies that measured HAI rates showed a reduction, although significance levels were not always stated.[25,30,33,36/37] Results were more mixed in four other systematic reviews reporting HAI data [27,31,35,43] and there were no significant decreases in HAI rates in relevant primary studies within two systematic reviews.[39,40] The final systematic review omitted to report HAI results.[42]

Intervention content and effectiveness

Table S7 summarises findings of 10 systematic reviews that considered the relationship between intervention content and effectiveness. One meta-analysis[38] indicated that interventions with more components, as conceptualised by WHO in their multimodal strategy

for HH,[2] did not see larger increases in HHC.[2] Conversely, within the same systematic review, two further meta-analyses of primary studies assessing the same combination of components showed that using all components of the WHO multimodal strategy for HH (OR 1.82, 95% CI 1.69-1.97) seems more effective in improving HHC than only including feedback, education, and reminders (OR 1.47, 95% CI 1.12-1.94).[38] Additionally, in a network meta-analysis,[30] interventions that supplemented the WHO multimodal strategy for HH with incentives, goal setting, or accountability produced further improvements in HHC than 'training and education' or 'system change' (OR not reported) and the WHO multimodal strategy for HH alone (OR 1.82, 95% credible interval 0.2-12.2). Doronina et al.[26] reached a similar conclusion in their narrative synthesis.

Naikoba and Hayward[18] emphasised that combining education with written material, reminders, and continued performance feedback can have a marked effect on HHC compared to single interventions comprising reminders or regular performance feedback, which in turn are more effective than one-off education and ABHR provision. Neo et al.[32] also proposed that effectiveness may be enhanced by multimodal interventions, as well as facilities design and planning and financial rewards. In another narrative synthesis, multimodal interventions supplying ABHR were as conducive to improving HHC as those without.[36/37] Meta-analytic findings suggest that providing (OR 2.81, 95% CI 1.32-5.96) than not providing (OR 1.55, 95% CI 1.13-2.11) performance feedback in a multimodal intervention is more likely to improve HHC.[33] In contrast, Cochrane authors concluded it is unclear whether multimodal over single interventions are preferable, or which components add most value.[27]

[2] Increase in HHC for interventions with one/two components (OR 3.44, 95% CI 1.11-10.68), three/four components (OR 2.16, 95% CI 1.82-2.55), and ≥five components (OR 2.49, 95% CI 1.74-3.56).

With regard to monitoring technology, Mitchell et al.[31] reported that devices delivering a real-time reminder that HH was indicated but not actioned were consistently linked to increased HHC, while systems with periodic feedback by managers produced variable findings. However, in assessing devices that give reminders without feedback, aggregate feedback without reminders, or individual feedback and reminders, Srigley et al.[40] found limited evidence to recommend any specific technology.

Delivery of educational interventions and effectiveness

Cherry et al.[25] considered the relationship between how the educational interventions were delivered and effectiveness. Delivery of education was separated into six groups education with: demonstration; no demonstration; self-study; video; demonstration and video and an online element. However, they could not identify one method of delivery that was more effective than another.[25]

Use of theoretical frameworks

Huis et al.[28] found a significant positive correlation between the effectiveness of interventions tested in controlled studies and the number of theoretical determinants of behaviour (one to five) addressed (r=.961, p=.009).[3] They also noted less commonly addressed determinants - social influence, attitude, self-efficacy, and intention - were mainly targeted in interventions addressing ≥four determinants.[28] Gould et al.[27] reported interventions mostly lacked convincing theoretical underpinning. Likewise, Srigley et al.[39] observed it was often unclear

[3] One theoretical determinant (n=3) - median relative difference (improvement) 17.6 [range -8.8 to 61]; two theoretical determinants (n=1) - relative difference (improvement) 25.7; three theoretical determinants (n=3) - median relative difference (improvement) 42.3 [range 19.5 to 82.7]; four theoretical determinants (n=2) - median relative difference (improvement) 43.9 [range 14.8 to 73]; five theoretical determinants (n=3) - median relative difference (improvement) 49.5 [range -8.6 to 429]; seven theoretical determinants (n=1) - relative difference (improvement) 9.7.

how theory informed interventions, that typically not all theoretical constructs were represented, and that measures of theoretical constructs were not always consistent with guidelines. No theoretical approach appeared more effective at improving HHC than another.[39]

Discussion

This systematic review has, for the first time, identified, described, and synthesised the existing evidence base of systematic reviews of interventions to improve HHC among HCW. In addition, the systematic review was conducted in a transparent and rigorous manner and benefited from a comprehensive literature search, spanning a wide time period with no language restrictions. Results of 15/18 systematic reviews that reported overall effectiveness showed positive effects of interventions on HCW HHC, across various healthcare settings for different professional groups. However, six of 11 systematic reviews that extracted HAI data described mixed or non-significant findings. Several reviewers advocated multimodal interventions, incorporating performance feedback and extending the WHO multimodal strategy for HH in particular, over single interventions to elicit improvements in HCW HHC. Still, this conclusion was not unanimous. Regarding theory, targeting higher numbers (up to five) of theoretical determinants of behaviour appears to increase effectiveness, with interventions that address social influence, attitude, self-efficacy, and intention especially effective. There was no clear link between how educational interventions were delivered and effectiveness.

Limits of the evidence and recommendations for practice

Although a substantial number of systematic reviews showed positive effects of interventions to improve HHC among HCW, only one systematic review had a low risk of bias.[27] This

systematic review concluded that there was sufficient evidence to recommend interventions to improve hand hygiene. However, the evidence on the optimum content and how it is should be delivered is unclear. In addition, evidence for the use of monitoring technology is insufficient to recommend their use.[31,40,43]. Theory informed interventions are recommended by the Cochrane systematic review.[27] The significant findings of Huis et al. [28] suggest that targeting social influence, attitude, self-efficacy and intention may enhance effectiveness, but the evidence base for this is small

Limits of the evidence and recommendations for future research

Caution is required when interpreting findings as only one systematic review was at low risk of bias. Reviewers should use quality assessment tools and follow best practice review guidelines[48–58] and ensure transparency in reporting of methods to minimise bias in future. Systematic reviews were restricted in that they largely comprised before-after studies; more robust study designs are required moving forward. Also, reviewers rarely conveyed the total sample size and the type of HCW was often not further defined. These reporting omissions likely reflect the absence of this detail in primary studies. However, this information is necessary to interpret generalisability, since what works in one population may differ to another.[59] .. A final comment about outcomes is that primary studies tended to run over short time periods, so the longer-term effect[60] of HH interventions has not yet been established. Researchers should consider this when designing studies.

Conclusions

This systematic review of systematic reviews has found predominantly low-quality evidence that interventions to improve HCW HHC are effective. There is sufficient evidence to recommend implementation of interventions to improve healthcare workers' HHC with the

exception of monitoring technology but insufficient to make specific recommendations about the content and how the content should be delivered. To fill existing research gaps, and develop a more viable evidence base to enable the generation of recommendations for practice, systematic reviews should follow reporting guidelines and primary studies need to utilise more robust research designs.

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Conflict of interest

LP is the Director of Studies for a PhD student (LG) whose study is being supported by SureWash. LP is leading, and LG is working on, another study supported by SureWash. LP and LG have two SureWash Elite machines on loan for data collection purposes for these two studies. All other authors report no conflicts of interest relevant to this article.

Authorship and manuscript preparation

No-one other than the named authors had a role in the gathering or preparation of data or in the writing of the manuscript. All authors made substantial contributions to the research and article, as follows:

1. The conception and design of the study (LP, JM, LG, PF, TH, JR) or acquisition of data (LP, JM, LG, LS, YW) or analysis and interpretation of data (LP, JM);
2. Drafting the article (JM) or revising it critically for important intellectual content (LP, LG, TH, PF, LS, YW, JR);
3. Final approval of the version to be submitted (LP, JM, LG, TH, PF, LS, YW, JR)

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Figure 1 PRISMA flow diagram outlining the systematic review selection process

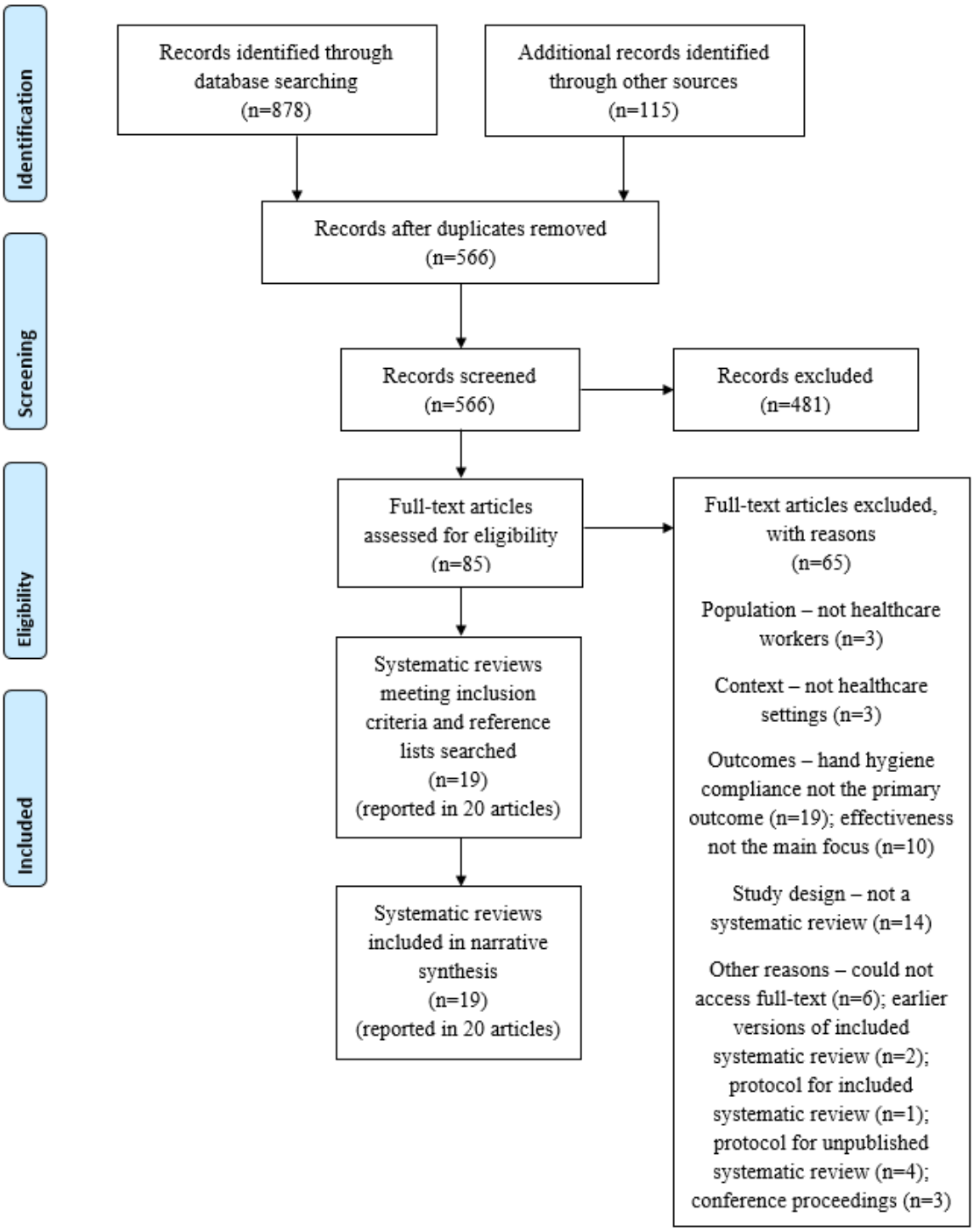

Table 1 Risk of bias within systematic reviews

First author (year)	Domain 1: Eligibility criteria	Domain 2: Identification and selection of studies	Domain 3: Data collection and study appraisal	Domain 4: Synthesis and findings	All concerns identified in domains 1 to 4 addressed in interpretation of findings?	Relevance of identified studies to the review's research question appropriately considered?	Emphasising results based on statistical significance avoided?	Overall judgement of risk of bias
	Level of concern							
Cherry et al. (2012)[25]	Unclear	Unclear	Low	High	No	Probably yes	Probably no	High
Doronina et al. (2017)[26]	High	Unclear	Unclear	High	No	Yes	Probably yes	High
Gould et al. (2017)[27]	Low	Low	Low	Low	Yes	Yes	Yes	Low

First author (year)	Domain 1: Eligibility criteria	Domain 2: Identification and selection of studies	Domain 3: Data collection and study appraisal	Domain 4: Synthesis and findings	All concerns identified in domains 1 to 4 addressed in interpretation of findings?	Relevance of identified studies to the review's research question appropriately considered?	Emphasising results based on statistical significance avoided?	Overall judgement of risk of bias
	Level of concern							
Huis et al. (2012)[28]	Unclear	Unclear	Low	Low	Probably no	Yes	Yes	Unclear
Kingston et al. (2016)[29]	High	High	High	High	No	Probably yes	Yes	High
Luangasanatip et al. (2015)[30]	High	Low	Unclear	Low	Probably no	Probably yes	Yes	Unclear
Mitchell et al. (2014)[31]	Unclear	High	High	High	No	Probably no	Yes	High

First author (year)	Domain 1: Eligibility criteria	Domain 2: Identification and selection of studies	Domain 3: Data collection and study appraisal	Domain 4: Synthesis and findings	All concerns identified in domains 1 to 4 addressed in interpretation of findings?	Relevance of identified studies to the review's research question appropriately considered?	Emphasising results based on statistical significance avoided?	Overall judgement of risk of bias
	Level of concern							
Naikoba & Hayward (2001)[18]	Unclear	High	High	High	No	Probably yes	Yes	High
Neo et al. (2016)[32]	Unclear	High	High	High	No	Probably yes	Probably yes	High
Ofek Shlomai et al. (2015)[33]	Unclear	High	Low	Unclear	No	Probably yes	No	High

First author (year)	Domain 1: Eligibility criteria	Domain 2: Identification and selection of studies	Domain 3: Data collection and study appraisal	Domain 4: Synthesis and findings	All concerns identified in domains 1 to 4 addressed in interpretation of findings?	Relevance of identified studies to the review's research question appropriately considered?	Emphasising results based on statistical significance avoided?	Overall judgement of risk of bias
	Level of concern							
Picheansathian et al. (2004)[34]	High	High	High	Unclear	No	No	Probably no	High
Ranji et al. (2007)[35]	Unclear	Low	Unclear	Low	Probably no	Probably yes	Yes	Unclear
Ritchie et al. (2005)[36]**/Stout et al. (2007)**[37]	Unclear	Unclear	High	High	No	Yes	Yes	High

First author (year)	Domain 1: Eligibility criteria	Domain 2: Identification and selection of studies	Domain 3: Data collection and study appraisal	Domain 4: Synthesis and findings	All concerns identified in domains 1 to 4 addressed in interpretation of findings?	Relevance of identified studies to the review's research question appropriately considered?	Emphasising results based on statistical significance avoided?	Overall judgement of risk of bias
	Level of concern							
Schweizer et al. (2014)[38]	Unclear	Unclear	High	High	Probably no	Probably yes	Yes	High
Srigley et al. (2015)[39]	High	Low	Low	Low	Probably no	Yes	Yes	Unclear
Srigley et al. (2015)[40]	High	Unclear	Low	Low	Probably no	Yes	Yes	Unclear
Stiller et al. (2016)[41]	High	Low	Unclear	High	No	Probably yes	Probably yes	High

First author (year)	Domain 1: Eligibility criteria	Domain 2: Identification and selection of studies	Domain 3: Data collection and study appraisal	Domain 4: Synthesis and findings	All concerns identified in domains 1 to 4 addressed in interpretation of findings?	Relevance of identified studies to the review's research question appropriately considered?	Emphasising results based on statistical significance avoided?	Overall judgement of risk of bias
	Level of concern							
Vindigni et al. (2011)[42]	Unclear	High	High	High	No	Probably yes	No	High
Ward et al. (2014)[43]	High	High	High	High	No	No	Yes	High

Supplementary material

Table S1 MEDLINE search

1.	(MH "Hand Hygiene+")
2.	TI "hand hygiene" OR AB "hand hygiene"
3.	TI "hand disinfection" OR AB "hand disinfection"
4.	TI handwashing OR AB handwashing
5.	TI "hand washing" OR AB "hand washing"
6.	TI (handrub* OR "hand rub*") OR AB (handrub* OR "hand rub*")
7.	TI "hand sanit*" OR AB "hand sanit*"
8.	TI "hand clean*" OR AB "hand clean*"
9.	TI "hand decontamination" OR AB "hand decontamination"
10.	TI "5 moments" OR AB "5 moments"
11.	TI "five moments" OR AB "five moments"
12.	TI "6 step*" OR AB "6 step*"
13.	TI "six step*" OR AB "six step*"
14.	TI ("alcohol based handrub" OR AB "alcohol based hand rub") OR AB ("alcohol based handrub" OR AB "alcohol based hand rub")
15.	TI "alcohol based hand sanit*" OR AB "alcohol based hand sanit*"
16.	TI "hand gel" OR AB "hand gel"
17.	TI (ABHR OR ABHS) OR AB (ABHR OR ABHS)
18.	OR/1-18
19.	(MH "Meta-Analysis as Topic")
20.	TI ("meta-analy*" OR metaanaly*) OR AB ("meta-analy*" OR metaanaly*)
21.	(MH "Meta-Analysis")

22.	TI (systematic W1 review*) OR AB (systematic W1 review*)
23.	TI (systematic W1 overview*) OR AB (systematic W1 overview*)
24.	(MH "Review Literature as Topic+")
25.	OR/19-24
26.	AB (cochrane OR medline)
27.	AB embase
28.	AB (psychlit OR psyclit OR psychinfo OR psycinfo)
29.	AB (cinahl OR cinhal)
30.	OR/26-29
31.	AB "reference list*"
32.	AB bibliograph*
33.	AB "hand search*"
34.	AB "relevant journal*"
35.	AB "manual search*"
36.	OR/31-35
37.	AB "selection criteria"
38.	AB "data extraction"
39.	OR/37-38
40.	(MH "Review")
41.	AND/39,40
42.	OR/25,30,36,41
43.	AND/18,42

Table S2 Standardised data extraction tool

FIRST REVIEWER:		
SECOND REVIEWER:		
BIBLIOGRAPHIC DETAILS	Study ID	
	First author, year of publication	
	Country	
	Type of review	
	Comments regarding type of review	
PURPOSE AND DATE RANGE OF REVIEW	Aim and objectives of review	
	Dates covered (from/to)	
PICOS ELIGIBILITY CRITERIA	Context eligibility criteria	
	Population eligibility criteria	
	Intervention eligibility criteria	
	Comparator eligibility criteria	
	Outcome eligibility criteria, including timeframe	
	Outcome: technique, opportunity, both	

	Comments regarding outcome	
	Study design eligibility criteria	
ANALYSIS OF INTERVENTIONS	Intervention content	
	Form of delivery	
	Use of theory in intervention development	
	Treatment fidelity	
	Intervention groupings	
	Review criteria for effectiveness	
RESULTS	Population	
	Comments regarding population	
	Total number of included studies	
	Number of studies per study type	
	Number of included studies per population	
	Total number of participants	
	Number of participants per population	
	Countries of included studies	

	Number of studies per healthcare setting	
	Number of studies per measure of hand hygiene	
	Effectiveness of interventions in terms of hand hygiene compliance	
	Effectiveness of interventions in terms of bacterial load, HAI rates, psychological variables, and/or organisational culture	
	Relationship between effectiveness and form of delivery	
	Relationship between effectiveness and intervention content	
	Relationship between effectiveness and use of theory in intervention development	
	Relationship between effectiveness and treatment fidelity	
	Other results	

DISCUSSION/CONCLUSIONS	Limitations	
	Key messages	
	Recommendations for practice	
	Future research	
REVIEWER COMMENTS	Any other comments relating to the review	

Table S3 ROBIS[23]

STUDY ID:		
FIRST AUTHOR, YEAR OF PUBLICATION:		
FIRST REVIEWER:		
SECOND REVIEWER:		
DOMAIN 1: Eligibility criteria	**Rating**	**Support for judgement**
Q1.1 Did the review adhere to pre-defined objectives and eligibility criteria?		
Q1.2 Were the eligibility criteria appropriate for the review question?		
Q1.3 Were eligibility criteria unambiguous?		
Q1.4 Were all restrictions in eligibility criteria based on study characteristics appropriate?		
Q1.5 Were any restrictions in eligibility criteria based on sources of information appropriate?		
JUDGEMENT DOMAIN 1: Concerns regarding specification of eligibility criteria		
DOMAIN 2: Identification and selection of studies	**Rating**	**Support for judgement**
Q2.1 Did the search include an appropriate range of databases/electronic sources for published and unpublished reports?		
Q2.2 Were methods additional to database searching used to identify relevant reports?		

Q2.3 Were the terms and structure of the search strategy likely to retrieve as many eligible studies as possible?		
Q2.4 Were restrictions based on date, publication format, or language appropriate?		
Q2.5 Were efforts made to minimise errors in selection of studies?		
JUDGEMENT DOMAIN 2: Concerns regarding methods used to identify and/or select studies		
DOMAIN 3: Data collection and study appraisal	**Rating**	**Support for judgement**
Q3.1 Were efforts made to minimise error in data collection?		
Q3.2 Were sufficient study characteristics available for both review authors and readers to be able to interpret the results?		
Q3.3 Were all relevant study results collected for use in the synthesis?		
Q3.4 Was risk of bias (or methodological quality) formally assessed using appropriate criteria?		
Q3.5 Were efforts made to minimise error in risk of bias assessment?		
JUDGEMENT DOMAIN 3: Concerns		

regarding methods used to collect data and appraise studies		
DOMAIN 4: Synthesis and findings	**Rating**	**Support for judgement**
Q4.1 Did the synthesis include all studies that it should?		
Q4.2 Were all predefined analyses followed or departures explained?		
Q4.3 Was the synthesis appropriate given the nature and similarity in the research questions, study designs and outcomes across included studies?		
Q4.4 Was between-studies variation (heterogeneity) minimal or addressed in the synthesis?		
Q4.5 Were the findings robust, e.g. as demonstrated through funnel plot or sensitivity analyses?		
Q4.6 Were biases in primary studies minimal or addressed in the synthesis?		
JUDGEMENT DOMAIN 4: Concerns regarding methods used to synthesise results		
Risk of bias in the review	**Rating**	**Support for judgement**
A. Did the interpretation of findings address all of the concerns identified in domains 1 to 4?		

B. Was the relevance of identified studies to the review's research question appropriately considered?
C. Did the reviewers avoid emphasising results on the basis of their statistical significance?
OVERALL JUDGEMENT OF RISK OF BIAS IN THE REVIEW
GUIDANCE - DOMAIN JUDGEMENTS If the answers to all questions for a domain are ‘yes’ or ‘probably yes’, then level of concern can be judged as low. If any signalling question is answered ‘no’ or ‘probably no’, potential for concern about bias exists. Low risk of bias: The findings of the review are likely to be reliable. The assessment of risk of bias in the review did not raise any concerns with the review process or concerns were appropriately considered in the review conclusions. The conclusions were supported by the evidence and included consideration of the relevance of included studies. High risk of bias: One or more of the concerns raised during the assessment of risk of bias in the review was not addressed in the review conclusions, the review conclusions were not supported by the evidence, or the conclusions did not consider the relevance of the included studies to the review question. Unclear risk of bias: There is insufficient information reported to make a judgement on risk of bias.

Table S4 Characteristics of included reviews

First author (year) and title	**Aim(s) of review**	**Review type and dates covered by the search**	**Inclusion criteria**	**Number, study design, countries, population and sample size, and healthcare settings of primary studies**	**Key outcomes, with operationalisations and measures for HHC, where discernible***
Cherry et al. (2012)[25] Features of educational interventions that lead to compliance with HH in healthcare	To determine the features of structured educational interventions that impact on compliance with HH in healthcare professionals within a hospital	Narrative synthesis 1995 to March 2011	*Context*: Hospital settings *Population*: Healthcare professionals *Interventions*: Structured educational interventions designed to change staff behaviour with regards to compliance of one or more facet of HH, documentable	30 studies (designs NR) USA (n=12), China (n=3), Thailand (n=2), Brazil (n=2), Germany (n=2), Australia (n=2), Philippines (n=1), Netherlands (n=1), Switzerland (n=1), Spain (n=1), Argentina (n=1),	<u>HHC (n=25**)</u>: *Unable to determine whether opportunity and/or technique* • Variation in HHC outcome measures (no further details given) <u>HAI rates (n=21**)</u>

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
professionals within a hospital care setting. A BEME systematic review: BEME Guide No. 22	care setting		and repeatable content, run over defined time period *Comparators*: Any, including but not limited to use of a control group, a differing educational intervention and use of differing healthcare groups *Outcomes*: At least one outcome measure of aseptic HH, pre- and	UK (n=1), Taiwan (n=1) Nurses and doctors, including postgraduate trainees (n=25), doctors only (n=2), nursing staff only (n=2), unspecified healthcare professional group (n=1) Sample sizes NR	

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
			post-intervention data relating to either patient outcomes or staff behavioural change, reports adequate descriptive statistics to evaluate the effectiveness of an intervention, and at least six months follow-up period *Study designs*: All study designs	PICU (n=7), NICU (n=5), hospital(s) (n=14), wound care centre (n=1), acute care facilities (n=1), adult cardiac surgical unit (n=1), paediatric nephrology unit (n=1)	
Doronina et al. (2017)[26]	To determine the short- and long-	Narrative synthesis	*Context*: Acute care hospital setting (no simulated	6 studies (3 RCT, 2 ITS, 1 CBA)	HHC (n=6): *Opportunity*

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
	term effects of interventions to improve HHC among nurses in the hospital setting		environments)		• Direct observation (n=4) • Unobtrusive observation (n=1)
A systematic review on the effectiveness of interventions improve HHC of nurses in the hospital setting		Searched reference list of review by Luangasanatip et al. (2015) and database searches from February 2014 (end date not	*Population*: Nurses (no students) *Interventions*: Interventions consisting of any strategy targeting promotion of hand washing *Comparators*: Not specified	Countries NR 277 nurses (n=4) Nursing wards (n=1), surgical wards (n=1), ICU (n=2)	*Usage of hand sanitiser* • Volume of liquid in mL (n=1)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
		given)	*Outcomes*: Direct or unobtrusive observation, electronic monitoring, or video recording to measure HHC rates, and proxy indicators, such as the amount of hand sanitiser used *Study designs*: RCT, ITS, and CBA studies meeting Cochrane EPOC methodological critiera		
Gould et al.	To assess the	Narrative	*Context*: Hospitals, nursing	26 studies (2 RCT, 9 CRT,	HHC (n=26):

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
(2017)[27] Interventions to improve HHC in patient care	short- and long-term success of strategies to improve HHC in patient care To determine whether an increase in HHC can reduce rates of HAI	synthesis 1980 to October 2016	homes, LTCF, or community healthcare settings in any country *Population*: Nurses, doctors, and other healthcare workers whose role does not involve in surgical hand disinfection and surgical scrubbing *Interventions*: Any intervention	2 stepped-wedge CRT, 1 randomised trial with crossover, 2 NRT, 10 ITS) Southeast Asia (n=4), Spain (n=1), Canada (n=1), England and Wales (n=1), Southern Ireland (n=1), Switzerland (n=2), Australia (n=1), Lebanon (n=1), Netherlands (n=1),	*Opportunity* • Direct observation (n=19) • Video camera (n=1) • Electronic monitoring device (n=1) *Proportion of nurses who performed HH* • Direct observation (n=1)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
			intended to improve compliance with HH using soap and water and/ or alcohol-based products *Comparators*: Not specified *Outcomes*: HHC measured through observation or a proxy indicator of HHC (primary outcome), HAI, and colonisation rates by clinically significant	Argentina (n=1), USA (n=10), multinational involving multiple European countries (n=1) as well as Israeli centres (n=1) Staff in the anaesthetic room (n=1), nurses (n=2) including student nurses (n=1) or nursing assistants	*HH events per hour* • Direct observation (n=1) *Product usage* • ABHR use in ounces per adjusted patient-day (n=1) • Litres of HH product per 100 patient-days

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
			nosocomial pathogens (secondary outcomes) *Study designs*: RCT, NRT, ITS, and CBA studies meeting Cochrane EPOC methodological criteria	and physiotherapists (n=1), all clinical staff present in the clinical areas during data collection (n=21) Sample sizes NR LTCF (n=2), primary care (n=1), acute care hospitals on general wards and/or critical care units (n=22),	(n=1) • Electronic count of soap/ABHR dispensers (n=1) • Procurement of ABHR (n=1) <u>HAI rates (n=7)</u>

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
				anaesthetic room (n=1)	
Huis et al. (2012)[28] A systematic review of HH improvement strategies: A behavioral approach	To offer sufficient conceptual clarity on the nature of HH improvement strategies by classifying their improvement activities on the basis of their determinants of	Narrative synthesis January 2000 to November 2009	*Context:* Hospital settings *Population*: HCW *Interventions*: Strategies aimed at improving HH behaviour *Comparators*: HH behaviour before the introduction of the programme or strategy, or HH	41 studies (28 before-after, 7 CBA, 3 RCT, 3 cross-over) Asia (n=7), Australia (n=3), Canada (n=1), Central America (n=1), Europe (n=5), Russia (n=1), South America (n=2), USA (n=21)	<u>HHC (n=41)</u>: • Unobtrusive observations (n=30) • Obtrusive observations (n=9) *HH episodes* • Electronic counting device (n=1)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
	behaviour change To explore the effectiveness of targeting different determinants of behaviour change (using controlled studies)		behaviour in a comparison group where another programme or no programme (usual care) was implemented *Outcomes*: All operationalisations of HH behaviour *Study designs*: Studies with at least one outcome comparison	Nurses, physicians, and other HCW (n=28, although n=1 also included family/visitors), nurses only (n=6), HCW not further defined (n=7) 76,197 opportunities (n=32)	*Volume of soap or hand alcohol used* • Number of dispenser activations/patient-days (n=1)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
			with a randomised or nonrandomized comparison group, or a comparison with baseline data in the case of a single group before-after design	ICU (n=25), medical or surgical wards (n=10), emergency wards (n=4), all hospital wards (n=2)	
Kingston et al. (2016)[29] HH-related clinical trials reported since	To report the outcomes of a systematic search for peer-reviewed, published studies – especially clinical	Narrative synthesis December 2009 to February	*Context*: Acute, non-acute, long-term care of the elderly and primary care settings *Population*: Healthcare professionals	16 studies (all described as clinical trials, but ITS and before-after were included[46]) Netherlands (n=2), France	HHC (n=8 with pre- and post-intervention data): *Opportunity* • Observation (n=7)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
2010: A systematic review	trials – that focused on HHC among healthcare professionals	2014	*Interventions*: Interventions focused on HH *Comparators*: Not specified *Outcomes*: HHC measured either by observation or electronic counters, results of HHC rates published	(n=2), Spain (n=1), UK (n=1), USA (n=5), Australia (n=1), Hong Kong (n=2), Brazil (n=1) and across 19 resource-limited countries in Latin America, South America, Asia, the Middle East and Europe (n=1) HCW n=8,174, range 32 to	*Amount of ABHR dispensed* • Electronic recording device (n=1)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
			Study designs: Empirical studies/ clinical trials	4,221 (from 6 studies) 5,166 nurses, 688 physicians, 1,620 healthcare assistants, 526 other HCW (from 5 studies) Adult ICU (n=113), step-down ICU (n=2), NICU (n=11), PICU (n=9), care	

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
				of the elderly (n=93), wards (n=59), primary healthcare centres (n=11), whole organisation (n=1)	
Luangasanatip et al. (2015)[30] Comparative efficacy of interventions to promote HH in	To evaluate the relative efficacy of the WHO campaign and other interventions to promote HH among HCW in	Network meta-analysis 1980 to February 2014	*Context*: Hospital settings *Population*: HCW *Interventions*: Interventions to improve HHC	41 studies (6 RCT, 1 NRT, 32 ITS, 2 CBA) Low- or middle-income countries (n=5) All HCW with patient	HHC (n=41): *Opportunity* • Direct observation (n=28) • Video recorders and external observers (n=2)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
hospital: Systematic review and network meta-analysis	hospital settings and to summarise associated information on use of resources		*Comparators*: No restrictions on promotion of HH in the comparison group *Outcomes*: HHC using opportunities with pre-specified indications or using proxies linked to HHC (such as consumption of soap and ABHR)	contact (n=34, but n=1 also included relatives), only nurses and/or nursing assistants (n=6), nursing students (n=1) Sample sizes NR Whole hospital (n=17), hospital wards (n=21) (n=3 allocated interventions to specific HCW)	*Soap or ABHR consumption, HH events, or HH checklist score* • (n=19) <u>HAI and/or resistance rates (n=19)</u>

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
			Study designs: RCT, NRT, ITS, and CBA studies meeting Cochrane EPOC methodological criteria		
Mitchell et al. (2014)[31] Automated HH monitoring systems	To identify and summarise evidence on the effectiveness of devices that automatically monitor	Narrative synthesis 2003 to November 2013	*Context*: Implied hospitals *Populations*: Hospital staff *Interventions*: Automated devices that record HHC, store quantitative information for	14 studies (1 RCT, 1 NRT, 11 pre-post), but 1 with no quantitative results Countries NR	<u>HHC (n=12)</u>: *Opportunity* • Automated devices (n=12) *Product usage* • Use of hand sanitizer

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
	compliance of hospital staff with proper HH procedures		subsequent download and analysis by infection control staff, work for any or all hand disinfection methods including soap and water and use of waterless products, and measure compliance by individuals or by groups of users *Comparators*: All comparisons	HCW not further defined Sample sizes NR Healthcare settings not consistently reported, but included ICU (n=2), hematology unit (n=1), step-down unit (n=1)	(n=1) • Solution dispenses (n=1) <u>HAI rates (n=3)</u>

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
			Outcomes: Prevalence estimates of hand disinfection, administrator satisfaction with product and data analytics capabilities, HAI rates *Study designs*: Guidelines, systematic reviews, RCT or NRT		
Naikoba & Hayward (2001)[18]	To summarise and assess the effectiveness of	Narrative synthesis	*Context*: Healthcare settings *Population*: HCW	21 studies (17 uncontrolled trials, 2 RCT, 1 observational) ***	HHC (n=21): *Opportunity* • Observation (n=7)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
The effectiveness of interventions aimed at increasing handwashing in healthcare workers – A systematic review	interventions aimed at increasing compliance with handwashing in HCW	Search dates NR	*Interventions*: Interventions to promote handwashing *Comparators*: Not specified *Outcomes*: Compliance with handwashing *Study designs*: Not specified	Countries NR HCW (occasionally further defined) ranged from 12 nurses to 426 staff ICU (n=15), general hospital (n=4), care homes for people with disabilities (n=1)***	*Technique* • Observation (n=1) *Technique and hand washing frequency* • Observation (n=1) *Handwashing frequency* • Observation (n=8)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
					• Soap use per day (n=1) *Handwashing behaviour* • Observation (n=3)
Neo et al. (2016)[32] Evidence-based practices to	To provide a comprehensive summary of recently published evidence-based	Narrative synthesis January 1, 2002 to	*Context*: Healthcare environments in developed countries *Population*: HCW, physicians,	73 studies (37 pre- and post-intervention studies without a control group, 21 pre- and post-intervention studies with a control	HHC (n=73): *Unable to determine whether opportunity and/or technique* • A mixture of HHC

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
increase HHC in healthcare facilities: An integrated review	HH interventions designed to improve HHC that will enable healthcare providers to make informed choices when allocating limited resources to improve HHC and patient safety	September 30, 2015	registered nurses, nursing students, families and visitors, and patients *Interventions*: Various forms of HH interventions *Comparators*: Not specified *Outcomes*: Measurements of improvement in HHC	group, 9 NRT, and 6 RCT) Developed countries HCW not further defined (n=51), registered nurses, nursing assistants, and students (n=17), families and visitors (n=5), physicians (n=3), patients (n=1)	measures, including self-report, electronic monitoring, and direct observation

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
			Study designs: RCT, NRT, and pre- and post-intervention designs with or without a control group	Sample sizes NR Entire facility (n=16), ICU (n=28), non-ICU inpatient units (n=27), LTCF (n=5), other locations (n=4)	
Ofek Shlomai et al. (2015)[33] Efficacy of	To evaluate the efficacy of strategies for improving HHC in	Meta-analysis Database	*Context*: NICU *Populations*: Implied HCW	16 studies (all non-randomised) Canada (n=1), Saudi	HHC (n=16): *Opportunity* • Observation (n=15) • Observation and

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
interventions to improve HHC in neonatal units: A systematic review and meta-analysis	NICU	inception to October 2013	*Interventions*: Interventions aimed to improve HHC *Comparators*: Not specified *Outcomes*: HHC *Study designs*: Randomised and before-after studies	Arabia (n=1), Netherlands (n=3), Philippines (n=1), Thailand (n=2), Switzerland (n=1), USA (n=3), Brazil (n=1), Taiwan (n=1), Hong Kong (n=1), and Russia (n=1) HCW not further defined HH opportunities	electronic dispensers (n=1) Blood culture positive HAI rates (n=9)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
				(n=27,155) NICU (n=16)	
Picheansathian (2004)[34] A systematic review on the effectiveness of alcohol-based solutions for	To evaluate the clinical evidence supporting the use of alcohol-based solutions in hospitals as an alternative for ensuring HH	Meta-analysis January 1992 to April 2002	*Context*: Hospitals *Population*: HCW *Interventions*: Introduction of alcohol-based solutions *Comparators*: Not specified	6 studies (designs NR) Countries NR Nurses, physicians, and other HCW (n=4) Sample sizes NR	<u>HHC (n=6)</u>: *Unable to determine whether opportunity and/or technique* • HHC measures NR

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
HH					
			Outcomes: HHC *Study designs*: Not specified	ICU and other wards, including gynaecology/obstetrics and paediatric	
Ranji et al. (2007)[35] Closing the quality gap: A critical	To determine the effects of quality improvement strategies on promoting adherence to	Narrative synthesis Database inception to December	*Context*: Acute care hospitals *Populations*: Implied HCW *Interventions*: Quality improvement strategies	11/64 studies of HH intervention with HHC and/or infection rate(s) outcome and 4/64 studies of bundle with HH component and HHC	<u>HHC (n=9)</u>: *Unable to determine whether opportunity and/or technique* • HHC measures NR

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
analysis of quality improvement strategies	interventions for prevention of selected HAI and on HAI rates	2005 / January 2006	*Comparators*: Not specified *Outcomes*: Incidence of HAI or adherence to evidence-based preventive interventions, including HH (where HAI also reported) *Study designs*: Experimental design with a control group	outcome (all before-after) Taiwan (n=1), Guatemala (n=1), Sri Lanka (n=1), USA (n=5), Mexico (n=1), Hong Kong (n=1), Netherlands (n=1), UK (n=1), Argentina (n=3) All clinical staff (n=5), nurses and physicians	HAI rates (n=15)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
			(RCT or quasi-RCT, CBA study) or a quasi-experimental design (ITS or before-after study)	(n=7), nurses only (n=1), HCW not further defined (n=2) Sample sizes NR NICU (n=2), ICU (n=5), surgical ICU (n=2), medical-surgical ICU (n=2) multiple areas of hospital (n=1), community	

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
				hospital with residents (n=1), unit/hospital type not specified (n=2)	
Ritchie et al. (2005)[36]**/Stout et al. (2007)**[37] The provision of alcohol-based products to improve	To determine the effectiveness of alcohol-based HH products in improving HHC and in reducing the incidence of HAI	Narrative synthesis Searches conducted May to November 2004 (no	*Context*: Hospitals *Populations*: Implied HCW *Interventions*: Interventions designed to improve HHC and interventions including a HH component designed to reduce	<u>For studies reporting HHC†</u> 41 studies (30 uncontrolled prospective, 8 prospective with non-randomised parallel control groups, 3 cross-over)	<u>HHC (n=41†)</u>: *Opportunity* • Direct observation (n=32) • Self-report (n=1) *Product usage* • (n=8)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
compliance with HH / Clinical effectiveness of alcohol-based products in increasing HHC and reducing infection rates: A systematic review		early cut-off date indicated)	nosocomial infection rates *Comparators*: Not specified *Outcomes*: HHC (not solely technique or handwashing duration), incidence of nosocomial infections *Study designs*: Primary studies with a pre-intervention measure	USA (n=17), Australia (n=4), Switzerland (n=3), France (n=3), UK (3), Costa Rico (n=1), Guatemala (n=1), Russia (n=1), Canada (n=1), Argentina (n=1), Taiwan (n=1), NR (n=5) Nurses only (n=5), nurses and healthcare assistants	HAI rates (n=27‡)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
			of HHC or infection rate	(n=3), medical staff only (n=2) nurses (including nursing assistants) and medical staff (n=3), mixed HCW (n=11), all HCW (15), not stated (n=2) Sample sizes NR ICU (n=25), other settings included paediatric	

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
				outpatient clinic, paediatric hospital, emergency department, general hospital(s), surgical wards, community hospitals, rehab unit, LTCF, renal unit, intermediate care unit <u>For studies reporting HAI‡</u> 27 studies (majority prospective design)	

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
				Countries NR HCW not further defined and sample sizes NR ICU (n=10), NICU (n=5), hospital-wide (n=5), LTCF (n=3), one or several departments (n=4)	
Schweizer et al.	To systematically	Meta-	*Context*: Healthcare settings	45 studies (39 quasi-	HHC (n=45):

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
(2014)[38] Searching for an optimal HH bundle: A meta-analysis	review all studies on interventions to improve HHC in order to evaluate existing compliance improvement bundles and identify areas of promise to target high quality	analysis January 2000 to April 2012	*Populations*: Healthcare professionals *Interventions*: Interventions to improve HHC *Comparators*: Any control group *Outcomes*: Numerator and denominator data on changes in	experimental, 4 CRT, 2 RCT) reported in 46 articles Europe (35.6%) and USA (34.1%) HCW not further defined Sample sizes NR	*Opportunity* • Direct observation (n=28) • Direct observation and electronic surveillance (n=2) • Direct observation and product usage (n=3) • Undercover observers and product usage

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
	intervention studies To evaluate the association between number of interventions in a HH bundle and improvement in compliance to determine whether		HHC (not self-report or ABHR use only) *Study designs*: RCT and quasi-experimental studies, including before-after studies with historical control groups	ICU (n=23), acute care units (n=14) entire hospital (n=7), LTCF (n=2), outpatient clinics (n=1), dialysis units (n=2), infectious disease unit (n=1), hematopoietic stem cell transplant/haematology unit (n=1)	(n=1) • Electronic surveillance (n=1) • Video surveillance (n=2) • Nurse investigators (n=1) • NICU medical staff (n=1) • Unknown (n=1)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
	bundle size has an effect on compliance				*Activation/use of dispenser* • Electronic surveillance (n=1) • Electronic surveillance and product usage (n=1) *Unknown/not stated* • Direct observation and product usage

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
					(n=1) • Direct observation (n=2)
Srigley et al. (2015)[39] Applying psychological frameworks of behaviour change to	To determine the effectiveness of interventions based on psychological frameworks to improve HCW HHC	Narrative synthesis Database inception to June 5, 2014	*Context*: Any healthcare setting, including acute care and long-term care *Populations*: Any HCW group *Interventions*: Interventions based on psychological theory to	4/7 intervention studies (1 stepped-wedge CRT, 1 CBA, 1 CBA and ITS, 1 before-after) UK (n=1), USA (n=2), and Australia (n=1)	HHC (n=4): *Unable to determine whether opportunity and/or technique* • Direct observation (n=4) *ABHR and soap*

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
improve HCW HH: A systematic review			improve HCW HH *Comparators*: Not specified *Outcomes*: HHC (not self-report) *Study designs*: RCT NRT, ITS, CBA studies, and quasi-experimental studies (including before-after)	1,203 nurses and personal care assistants (n=1), nurses, medical staff, and allied health practitioners (n=1) 44,730 HH opportunities (n=2) Acute general and teaching hospitals (n=1), tertiary	*procurement* • (n=1) HAI rates (n=3)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
				care teaching hospital (n=1), tertiary care hospital (n=1), teaching hospitals (n=1)	
Srigley et al. (2015)[40] HH monitoring technology: A systematic review of	To determine whether HH monitoring technology increases directly observed HHC among HCW	Narrative synthesis Database inception to December 31st 2013	*Context*: Acute or long-term care settings *Populations*: HCW *Interventions*: HH monitoring technology	7 studies (1 RCT, 1 NRT, 2 ITS, 3 pre-test post-test) Countries NR All HCW (n=2), all HCW and visitors (n=3), and 245	<u>HHC (n=7)</u>: *Opportunity* • System defined (n=5) • System defined and HH event rate (n=1) *HH frequency*

First author (year) and title	**Aim(s) of review**	**Review type and dates covered by the search**	**Inclusion criteria**	**Number, study design, countries, population and sample size, and healthcare settings of primary studies**	**Key outcomes, with operationalisations and measures for HHC, where discernible***
efficacy	compared to usual care To determine whether HH monitoring technology reduces HAI incidence or improves other measures of HH,		*Comparators*: Usual care *Outcomes*: HHC (not at ward/ hospital entrances or in the operating room) and/or HAI incidence *Study designs*: Experimental and quasi-experimental studies	nurses (n=2) Median (range) number of HH opportunities 194,150 (8,235-1,017,600) Intermediate care unit (n=1), haematology ward (n=1), medical ICU (n=1), surgical ICU (n=1), step-down units (n=1), chronic	• (n=1) *ABHR usage* • (n=2) <u>HAI rates</u>: (n=2)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
	including HH frequency, volume of soap and ABHR use, or compliance as defined by the individual HH monitoring technology			care ward (n=1), wards and surgical ICU (n=1)	
Stiller et al. (2016)[41]	To analyse whether healthcare facility design is a	Narrative synthesis	*Context*: Hospitals *Population*: Implied HCW	3 studies (designs NR) Countries NR	<u>HHC (n=3)</u>: *Opportunity* • Anonymous recording

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
Relationship between hospital ward design and HAI infection rates: A systematic review	contributing factor to multifaceted infection control strategies (e.g. the impact of the accessibility of antiseptic handrub dispenser's location on HHC)	January 1, 1990 to December 31, 2015	*Interventions*: Antiseptic hand rub dispenser inside the patient's room *Comparators*: Different location of antiseptic hand rub dispenser inside the patient's room *Outcomes*: HHC rate or antiseptic agent consumption	52 physicians (n=1), HCW not further defined (n=2) Real-size patient room replica (n=1), internal medical unit (n=1), surgical ICU (n=1)	(n=1) • Observation (n=1) *Daily volume of use of antiseptic hand rub* • (n=1)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
			volume *Study designs*: Any type of study or trial		
Vindigni et al. (2011)[42] Systematic review: Handwashing behaviour in	To describe global approaches to handwashing research in low- and middle-income communities,	Narrative synthesis Database inception to August 2009	*Context*: Healthcare settings in low- or middle-income countries *Population*: Not specified *Intervention*: HH interventions	7/30 studies of interventions in healthcare settings (6 quantitative, 1 mixed methods) Low- and middle-income countries	HHC: *Unable to determine whether opportunity and/or technique* • Direct observation (n=6) • Self-report (n=1)

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
low- to middle-income countries: Outcome measures and behaviour maintenance	schools and healthcare settings using behavioural outcome measurement and temporal study design		*Comparator*: Not specified *Outcome*: HH behaviour (self-report, proxy indicator, and/or direct observation) *Study design*: Not specified	HCW not further defined Sample sizes NR Outpatient maternal-child health clinic (n=1), hospital (n=1), other settings NR	*Soap presence* • (n=2) <u>HAI rates (n=3)</u>
Ward et al. (2014)[43]	To assess the existing evidence surrounding the	Narrative synthesis	*Context*: Healthcare settings *Populations*: Implied HCW	42 studies (designs not consistently reported)	<u>HHC (n=unclear)</u>: *Unable to determine whether opportunity*

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
Automated and electronically assisted HH monitoring systems: A systematic review	adoption and accuracy of automated systems or electronically enhanced direct observations and review the effectiveness of such systems in healthcare settings	January 1, 2000 to March 31, 2013	*Interventions*: Automated and electronically assisted HH monitoring systems *Comparators*: Not specified *Outcomes*: Implied accuracy of monitoring technology or HHC *Study designs*: Not specified	Countries NR HCW not further defined (in at least 1 study, HHC data was collected for all entrances made by patients and visitors, as well as HCW) Sample sizes NR	*and/or technique* • HHC measures included electronic dispenser systems, automated monitoring networks, video camera, and mobile handheld devices <u>HAI rates (n=unclear)</u>

First author (year) and title	Aim(s) of review	Review type and dates covered by the search	Inclusion criteria	Number, study design, countries, population and sample size, and healthcare settings of primary studies	Key outcomes, with operationalisations and measures for HHC, where discernible*
				Healthcare settings not consistently reported, but appears to be hospitals only	

Note. ABHR = Alcohol-based hand rub. CBA = Controlled before-after. CRT = Cluster randomised trial. EPOC = Effective Practice and Organisation of Care. HAI = Healthcare associated infection. HCW = Healthcare workers. HH = Hand hygiene. HHC= Hand hygiene compliance. ICU = Intensive care unit. ITS = Interrupted time series. LTCF = Long-term care facilities. NICU = Neonatal intensive care units. NR = Not reported. NRT = Non-randomised trials. PICU = Paediatric intensive care units. RCT = Randomised controlled trials. UK = United Kingdom. USA = United States of America. WHO = World Health Organization. * = Some primary studies within some reviews reported more than one measure of HHC. ** =Figures derived from Table 5 in Cherry et al (2012).[25] *** = Naikoba and Hayward (2001)[18] only reported study designs and healthcare settings for 20/21 primary studies. † = From Ritchie et al. (2005).[36] ‡ = From Stout et al. (2007).[37]

Table S5 Mapping content of interventions included in reviews onto the World Health Organization's (2009) multimodal strategy for hand hygiene

First author (year)	System change	Training and education	Observation and feedback	Reminders	Safety climate	Total
Cherry et al. (2012)[25]	X	X	X	X	X	5
Doronina et al. (2017)[26]	X	X	X	X	X	5
Gould et al. (2017)[27]	X	X	X	X	X	5
Huis et al. (2012)[28]		X	X	X	X	4
Kingston et al. (2016)[29]	X	X	X	X	X	5
Luangasanatip et al. (2015)[30]	X	X	X	X	X	5
Mitchell et al. (2014)[31]		X	X	X		3
Naikoba & Hayward (2001)[18]	X	X	X	X		4
Neo et al. (2016)[32]	X	X	X	X	X	5
Ofek Shlomai	X	X	X	X		4

First author (year)	System change	Training and education	Observation and feedback	Reminders	Safety climate	Total
et al. (2015)[33]						
Picheansathian (2004)[34]		X	X			2
Ranji et al. (2007)[35]		X	X	X	X	4
Ritchie et al. (2005)[36]**/Stout et al. (2007)**[37]	X	X	X	X		4
Schweizer et al. (2014)[38]	X	X	X	X	X	5
Srigley et al. (2015)[39]	X	X	X			3
Srigley et al. (2015)[40]			X	X		2
Stiller et al. (2016)[41]	X					1
Vindigni et al. (2011)[42]	X	X	X			3
Ward et al. (2014)[43]			X	X	X	3
Total	13	16	18	15	10	

Table S6 Overall effectiveness of interventions (hand hygiene compliance)

First author (year)	Overall intervention effectiveness (HHC)
Cherry et al. (2012)[25]	21/25 studies that reported HHC showed a significant improvement (p=.05 to p<.001).*
Doronina et al. (2017)[26]	HHC improved in all six studies (p<.05 in two studies). Increases of 4%, 13%, 16%, and 35% in HHC in three studies (p NR) and an increase from 20% to 53% (OR=1.64) in the sixth study. Improvement was maintained at 3 to 6 months in four out of six studies.
Gould et al. (2017)[27]	Overall, HHC increased in all studies, regardless of the intervention or the outcome measure employed. The level of increase varied, however, as did the level of HHC both at baseline and post-intervention.
Huis et al. (2012)[28]	The effectiveness of the strategies used in controlled studies (n=13) varied substantially, but most showed positive results.
Kingston et al. (2016)[29]	Overall, based on mean HHC rates calculated from 8 studies with baseline and post-intervention data, there was an improvement of 22.8%, from 34.1% at baseline to 56.98% after intervention (p NR).
Luangasanatip et al. (2015)[30]	Of 22 pairwise comparisons from ITS studies, 18 showed both stepwise increases in HHC associated with intervention and increases in mean HHC after intervention compared with that expected in the absence of intervention. The range was wide: the mean change in HHC attributed to intervention varied between a decrease of 14.8% and an increase of 83.3%.
Mitchell et al. (2014)[31]	9/12 studies reported an increase in HHC (1 study had no quantitative results). Where only the increase in HHC is given, there were 7%, 34%

First author (year)	Overall intervention effectiveness (HHC)
	and 40% increases in HHC rates (p NR). Pre- and post-intervention HHC rates were reported for four studies (p NR) and ranged from 23% to 88% and from 48% to 98%, respectively.
Neo et al. (2016)[32]	Five HH intervention types were found to be effective. Among studies that reported the p value (n=63/73), 59 produced a significant increase in HHC.**
Ofek Shlomai et al. (2015)[33]	Meta-analysis (n=14) indicated an improvement in HHC (OR=2.04, 95% CI=1.40-2.97; I2=97%). Two studies that could not be included in the meta-analysis also showed improved HHC (p NR (n=1), p=.001 (n=1)).
Picheansathian (2004)[34]	The combined result of six studies significantly favoured the introduction of ABHR (Peto OR=1.96, CI=1.56-2.46).
Ranji et al. (2007)[35]	6/9 studies reported a significant improvement in HHC (all p<.01) with baseline data ranging from 5% to 62% and post-intervention data ranging from 53% to 85%, 2/9 studies reported an improvement in HHC (17% to 30% p NR and 40% to 58% p NR), and 1/9 studies reported an 11% change in HHC (p NR).
Ritchie et al. (2005)[36]/ **Stout et al. (2007)**[37]	Most types of interventions employed in infection control generate at least transient improvements in HHC.
Schweizer et al. (2014)[38]	37/45 studies reported a significant improvement in HHC (p NR).
Srigley et al.	Four studies utilising a theoretical approach reported overall improvement

First author (year)	Overall intervention effectiveness (HHC)
(2015)[39]	in HHC (p<.001 for n=2; OR=1.44, p<.001 (n=1); increase of 15%, p=.039).
Srigley et al. (2015)[40]	Insufficient evidence was found to recommend adoption of HH monitoring technology in general as a HHC improvement strategy (3/7 studies reported significant increases).
Stiller et al. (2016)[41]	There were significant increases in HHC in all 3 studies.
Vindigni et al. (2011)[42]	The evidence base documents short-term improvement in HHC among HCW in low- to middle-income healthcare facilities. Data provided for 1/7 studies, where there was a 31% to 40% increase in HHC (p NR).
Ward et al. (2014)[43]	There is very little data as to whether automated and electronically assisted systems monitoring systems can improve HHC.

Note. ABHR = Alcohol-based handrub. CI = Confidence interval. HCW = Healthcare workers. HH = Hand hygiene. HHC = Hand hygiene compliance. ITS = Interrupted time series. NR = Not reported. OR = Odds ratio. * = Figures derived from Table 5 in Cherry et al (2012).[25] ** = From the article text, although Table A2 in Neo et al. (2016)[32] indicates that 62 rather than 63 studies reported a p value and that 58 rather than 59 studies produced a significant increase in HHC.

Table S7 Relationship between intervention content and effectiveness (hand hygiene compliance)

First author (year)	Intervention content and effectiveness (HHC)
Doronina et al. (2017)[26]	Single-component interventions were shown to improve HHC, but evidence showed sustainable and greater improvements with multimodal strategies. Education, feedback and support from a team leader, accessibility, and visual reminders of HH are all elements that appear to increase HHC in nurses. It is important to add goal setting, reward incentives, and accountability for further improvements.
Gould et al. (2017)[27]	*Multimodal interventions that include some but not all components recommended in the WHO multimodal strategy for HH, multimodal interventions that include all the recommended components plus additional strategies, and cues such as signs or scent*: May slightly improve HHC (low certainty evidence). *Multimodal interventions that contain all components recommended in the WHO multimodal strategy for HH*: Unclear whether improve HHC (very low certainty evidence). *Performance feedback and education*: May improve HHC (low certainty evidence). *Placement of ABHR close to point of use*: Probably slightly improves HHC (moderate certainty evidence).

First author (year)	Intervention content and effectiveness (HHC)
Huis et al. (2012)[28]	BCT that map on to the theoretical determinates of social influence (e.g. provide information about peer behaviour, provide opportunities for social comparison, mobilise social norm), attitude (e.g. persuasive communication, reinforcement of behavioural progress), self-efficacy (e.g. modelling, verbal persuasion, guided practice, plan coping responses, set graded tasks/goal setting), and intention (e.g. general intention information, agree to behavioural contract) appear to be associated with increased effectiveness of interventions.
Luangasanatip et al. (2015)[30]	Meta-analysis of two RCT showed that the addition of goal setting to the WHO-5 framework was associated with improved HHC over the WHO-5 framework alone (OR=1.35, 95% CI=1.04-1.76). Twelve pairwise comparisons from ITS met the criteria for network meta-analysis. When single interventions of education or system change (OR=4.30, 95% credible interval (CRI) 0.43-46.57), the WHO-5 framework (OR=6.51, 95% CRI 1.58-31.91), and the WHO-5 framework plus incentives, goal setting, or accountability (OR=11.83, 95% CRI 2.67-53.79) were compared with no intervention, there was evidence that they were all effective. The WHO-5 framework plus incentives, goal setting, or accountability also showed additional improvement compared with single interventions of education or system change (OR NR) and WHO-5 framework alone (OR=1.82, 95% CRI 0.2-12.2). The WHO-5 framework plus incentives, goal setting, or accountability had the highest probability (67%) of being the best strategy in improving HHC.

First author (year)	Intervention content and effectiveness (HHC)
Mitchell et al. (2014)[31]	*Real-time reminder systems*: 7/7 studies reported an improvement in HHC. *Periodic feedback given by managers*: 1/3 studies reported an improvement in HHC.
Naikoba & Hayward (2001)[18]	*One-off educational interventions (single intervention)*: 3/5 studies showed a short-term effect on handwashing (p<.0001, n=1), with HHC falling to low or baseline levels within a month for 2/3 studies. 1/5 studies reported an improvement in HHC maintained over six months (data and p NR). 1/5 studies found no significant difference in HHC between the intervention and control groups (p NR). *Reminders (single intervention)*: 1/4 studies found a significant 34% increase in soap use per bed day (p=.021), 1/4 studies found a significant increase in HH frequency (p<.05), and 2/4 studies reported no difference between pre- and post-intervention, but data provided only for one study (31% versus 30%, p=.25). *Performance feedback (single intervention)*: 2/4 studies reported improvements (p NR), 1/4 studies reported significant improvements for medical officers from 57% to 94% and for physiotherapists from 20% to 77% sustained at six months (p NR), and 1/4 studies reported a significant improvement compared to the control group over a three-week period (p<.05).

First author (year)	Intervention content and effectiveness (HHC)
	Moisturised soaps/ABHR near patient beds (single intervention): 1/3 studies reported a significant improvement from 32% to 45% (p NR), 1/3 studies reported no change (no data), and 1/3 studies reported a decrease from 76% to 24% which was attributed to a change of medical staff during the same period (p NR). *Adjusting sink facilities (single intervention)*: 1/2 studies reported a significant improvement in quality of handwashing (data and p NR) and 1/2 studies reported that handwashing was performed more frequently on wards with more sinks than on wards with fewer sinks (76% versus 51%, respectively, p NR). *Multiple interventions*: 4/6 studies reported a significant improvement (p<.01, n =3; p NR, n=1).
Neo et al. (2016)[32]	*Improving awareness with education (knowledge transfer, evaluation, monitoring, feedback)*: 26/34 studies found a significant % improvement in HHC (range from 4% to 70%*, p<.05 to p<.001) and 7/34 studies found a % improvement in HHC (range from 6% to 62%, all p NR). *Facility design and planning*: 7/8 studies found a significant % improvement in HHC (range from 14% to 60%, p=.01 to p<.001). *Unit-level protocols and procedures*: 6/7 studies found a significant %

First author (year)	Intervention content and effectiveness (HHC)
	improvement in HHC (range from 16% to 59%, all p<.001). *Institution-wide programmes*: 1/3 studies found a significant 20% improvement in HHC (p<.01) and 1/3 studies found a 43% improvement in HHC (p NR). *Multimodal interventions*: 16/21 studies found a significant % improvement in HHC (range from 8% to 200%, p<.05 to p<.001), 1/21 studies found a significant 48% improvement (p<.001) in HHC in one of three multimodal campaigns evaluated, 1/21 studies found a significant 9% improvement (p=.03) in HHC among nurses, but a significant 14% decline (p=.008) among physicians, and 3/21 studies found a % improvement in HHC (range from 36% to 49%, all p NR).
Ofek Shlomai et al. (2015)[33]	The provision of performance feedback in addition to other measures improved HHC markedly (OR=2.81, 95% CI=1.32-5.96) whereas studies that did not include the provision of performance feedback resulted in improvement of HHC to a lesser degree (OR=1.55, 95% CI=1.13-2.11).
Ritchie et al. (2005)[36]**/ Stout et al. (2007)**[37]	Successful interventions were generally multi-component in nature, long-term, and targeted a range of factors that modify HH behaviour. Multi-component strategies were more consistently associated with sustained improvements compared with single component strategies. Multi-component interventions that include ABHR products are equally effective as strategies that do not in effecting sustained change.

First author (year)	Intervention content and effectiveness (HHC)
	ABHR alone: 3/4 studies reported a significant improvement in HHC with increases of between 44% and 92% at 5 to 12 weeks (p<.05 to p=.007). *ABHR and education*: 3/7 studies reported a significant improvement in HHC with increases of between 41% and 139% (p<.01 to p<.001). *ABHR with multifaceted intervention*: 3/4 studies reported a significant improvement in HHC (p<.001; 1 study NR). Also, a significant increase in HHC was demonstrated in all 2 studies, with adjusted OR of 1.9 and 1.92 at 5.5 months and 3 years respectively. For 1/4 reported that significant improvement was observed; however, it is stated in the summary table that significant improvement was observed only when "relaxed criteria were used i.e. glove use before contact is adequate HH" – thus, this was not considered as a significant improvement to HHC. *Education alone*: 1/2 studies reported an increase in ABHR consumption (from 5.7 to 9.7 L per capita over an eight-year period, p NR). *Reminders alone*: 2/5 studies reported a significant increase in product usage (40% increase at three months, p <.001; average 34% increase during intervention period, p=.021).

First author (year)	Intervention content and effectiveness (HHC)
	Feedback alone: 1/4 studies significant improvement in HHC across staff groups (p=.001) and 1/4 studies significant improvement in HHC among two of six professional groups (p<.001). *Multifaceted interventions*: 11/15 studies significant improvement in HHC with increases ranging from 19% to 1160% (p <.05 to p<.0000 (sic)).
Schweizer et al. (2014)[38]	Studies that assessed a larger number of components to improve HH did not see larger increases in HHC: 1 or 2 components (OR=3.44, 95% CI=1.11-10.68, n=13); 3 or 4 components (OR=2.16, 95% CI=1.82-2.55, n=20); and ≥5 components (OR=2.49, 95% CI=1.74-3.56, n=12). Three studies of interventions that included feedback, education, and reminders were statistically significant (OR=1.47, 95% CI 1.12-1.94; I2=19%). Three studies of interventions that included feedback, education, reminders, access to ABHR, and administrative support (i.e. the WHO-5 framework) were statistically significant (OR=1.82, 95% CI=1.69-1.97; I2=11%).
Srigley et al. (2015)[40]	Insufficient evidence was found to recommend adoption of any specific HH monitoring technology as a HHC improvement strategy. *Electronic monitoring systems that provided reminders without feedback*:

First author (year)	Intervention content and effectiveness (HHC)
	2/2 studies reported a significant improvement (from 19.1% to 27.3% and from 36.3% to 70.1%) in HHC during the intervention period (p<.05). *Electronic/video monitoring systems that provided aggregate feedback without reminders*: 2/3 studies reported an improvement in HHC at room entry/exit (from 6.5% to 81.6% and from 30.4 % to 82.3% at 16 weeks of intervention; p NR) and 1/3 studies report no significant difference in HH frequency (p=.63). *Electronic monitoring systems that provided individual feedback and reminders*: 1/2 studies reported significantly higher (+6.8%) HHC in the intervention versus the control arm (p NR) and 1/2 studies reported an increase from 25% to 65% (p NR).

Note. ABHR = Alcohol-based hand rub. BCT = Behaviour change techniques. CI = Confidence interval. CRI = Credible interval. HH = Hand hygiene. HHC = Hand hygiene compliance. ITS = Interrupted time series. NR = Not reported. OR = Odds ratio. RCT = Randomised controlled trial. WHO = World Health Organization. WHO-5 = World Health Organization's (2009) multimodal strategy for hand hygiene. * = From the article text, although Table A2 in Neo et al. (2016)[32] shows that the upper limit of % improvement in HHC is 78% not 70%.